NAVPERS 93083A-3

TROUBLESHOOTING ELECTRONIC EQUIPMENT

TECHNICAL MANUAL FOR OSCILLOSCOPE, TS-0

VOL. 3

Bureau of Naval Personnel
Washington, D.C. 20370

INTRODUCTION

This instruction manual has been specifically designed for use with the automated text for Trouble-Shooting Electronic Equipment, NAVPERS 93083A-1 and 93083A-2. The manual is based upon an actual piece of Navy test equipment which is currently used in almost all Fleet activities. You should study the manual very carefully when directed to do so by the automated text. Volume 2 of the automated text can be completed only if the previous lessons on trouble-shooting principles have been learned and a thorough knowledge of this typical equipment has been acquired.

When ordering this publication, request NavPers 93083A-1, 93083A-2, and 93083A-3.

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TS-0 OSCILLOSCOPE

GENERAL DESCRIPTION

1. PURPOSE.

This instruction book describes Oscilloscope TS-0 and includes information concerning the operation and maintenance of the equipment as required for general equipment understanding. The manual is written specifically to accompany the automated text for Trouble-Shooting Electronic Equipment NAVPERS 93083A (Vol. 1, 2 and 3). This manual should be studied and its content understood prior to beginning lesson No. 8 of the automated text.

2. EQUIPMENT DESCRIPTION.

a. The TS-0 is a general purpose oscilloscope which has been specifically designed to be a light-weight, easily transportable test instrument. This oscilloscope is capable of visually displaying the results of any number of testing operations within its circuit capabilities. Some of these tests and measurements include alignment and testing of receiving and transmitting equipment, both radio and radar; hum measurements; frequency comparison; observing standard and complex signal voltage waveforms; percentage modulation measurements; etc.

b. Power required for the operation of the oscilloscope is readily available on board ship or in a shore installation, that is, 105-125 volts, 50-1000 cycles, ac, single phase.

c. Physically the TS-0 is 9" high, 6" wide, and 13-1/2" deep. The unit weighs 14 lbs without its carrying case.

d. The versatility of this instrument as a trouble-shooting aid has been demonstrated many times. The TS-0 itself is not infallible and will possibly require the same trouble-shooting procedures and related test equipment as any other electronic equipment to maintain it as a highly effective maintenance tool.

3. REFERENCE DATA.

The data given below is pertinent to the Electrical Characteristics of the TS-0 Oscilloscope.

a. Frequency Range:

(1) Vertical Amplifiers:
  (a) 0 to 2,000,000 cycles, at full gain control setting.
  (b) 5 to 2,000,000 cycles, attenuated a-c input to amplifiers.

(2) Horizontal Amplifiers:
  (a) 0 to 500,000 cycles at full gain control setting.
  (b) 1 to 500,000 cycles, independent of gain control setting.

(3) Internal Sweep Circuit Oscillator: 3 to 50,000 cycles:
   (a) 3 cycles is equivalent to a sweep time duration of 333,333 µsec.
   (b) 50 kc is equivalent to a sweep time duration of 20 µsec.

b. Input Impedance:

(1) Vertical: AC—1.5 megohms, shunted by 25 µµf. DC—2 megohms.
(2) Horizontal: AC—1.5 megohms, paralleled by 25 µµf. DC—2 megohms.
(3) Vertical, Direct: 9 megohms, shunted by 11 µµf.
(4) Horizontal, Direct: 9 megohms, shunted by 11 µµf.

c. Deflection Sensitivity:

(1) Vertical: Amplifier, .075 RMS volt/inch.
   Direct, approximately 17 RMS volts/inch.
(2) Horizontal: Amplifier, .075 RMS volt/inch.
   Direct, approximately 25 RMS volts/inch.

d. Power Consumption: 60 watts at 115 volts.

e. Over-all Accuracies:

(1) Vertical Amplifiers:
   (a) ±3 db from 0 to 2,000,000 cycles, at full gain control setting.
   (b) ±3 db from 5 to 2,000,000 cycles, independent of gain control setting.
(2) Horizontal Amplifiers:
   (a) ±3 db from 0 to 500,000 cycles, at full gain control setting.
   (b) ±3 db from 1 to 500,000 cycles, independent of gain control setting.
(3) Gain Stability; Horizontal and Vertical Amplifiers: ±3 db from 105 to 125-volt line supply.

f. Tube Complement:

V101A-V101B	12AT7WA	Vert Cath Follower-Sync Amplifier
V102A-V102B	12AT7WA	1st Vert D-C Amplifier
V103	6AH6	2nd Vert D-C Amplifier
V104	6AH6	2nd Vert D-C Amplifier
V105A-V105B	12AT7WA	Horiz Cathode Follower-Intensity Modulation Ampl
V106A-V106B	12AT7WA	1st Hor D-C Amplifier
V107A-V107B	6J6WA	2nd Hor D-C Amplifier
V108A-V108B	6J6WA	Sweep Circuit Oscillator
V109	3RP1	Cathode-Ray Tube
V110	6X4W	Intermediate Voltage Rectifier
CR101	Selenium	Low-Voltage Rectifier
CR102	Selenium	Low-Voltage Rectifier
CR103	Selenium	High-Voltage Rectifier

OPERATION

1. GENERAL.

This section gives the purpose and function of all operating controls and terminals of the TS-O oscilloscope. This oscilloscope is operated in a similar manner to any oscilloscope used for general purpose equipment testing. Certain adjustments are necessary to obtain an accurate presentation of the voltage waveshape to be observed on the cathode-ray-tube face of the oscilloscope.

2. CONTROLS AND THEIR FUNCTIONS.

The presentation below lists all operating controls and terminals by their names and reference designations, and also explains their purposes and functions. The locations of the controls are shown in the front and top views of the equipment, figures 1A and 1B (page 29, 30), respectively. Reference should be made to these illustrations for the location of the control or terminal under discussion.

a. INTENSITY-POWER ON (R176, S105). Operating this control clockwise turns the power on to the instrument; the pilot light (DS-109) will indicate that the instrument is on. As the control is operated further clockwise, it controls the intensity of the pattern or spot on the cathode-ray tube. When the control is in the full clockwise position, the pattern is at maximum brilliance.

b. FOCUS (R177). This control adjusts the focus, or sharpness, of the trace on the cathode-ray tube.

c. POSITIONING (LEFT-RIGHT, R136; DOWN-UP, R111). The purpose of the positioning controls is to adjust the position of the trace on the screen, either horizontally or vertically.

d. VERT. ATTEN. (S101).

NOTE

> Always operate the VERT. ATTEN. switch to the highest attenuator position in which suitable vertical deflection can be obtained. If this is not done, overloading of the cathode follower will generally result. Overloading can be detected by a clipping or squashing of the pattern.

This control attenuates the signal fed in at the vertical input (AC) connector by a factor of 1, 10, or 100. When turned to the DC position, it permits the d-c voltage fed in between the DC input and GND to be amplified by the vertical amplifier. Positive d-c voltages will cause the beam to move up on the screen.

e. VERT. GAIN (R104). This control is used as a vernier in connection with the VERT. ATTEN. control to adjust the height of the pattern on the screen in the case of a-c voltages; and, in the case of d-c voltages, the extent of deflection, either up or down, of the beam. The position of the VERT. GAIN control has no effect on band width when the attenuator is in any one of the AC positions; however, in the DC position the VERT. GAIN control affects the band width.

f. HOR. ATTEN. (S102). (The note under VERT. ATTEN. also applies to the HOR. ATTEN. control.)

This control attenuates the signal fed in at the horizontal input (AC) connector by a factor of 1, 10, and 100. When turned to the DC position, it permits the d-c voltage fed in between the DC input and GND. to be amplified by the horizontal amplifier. Positive d-c voltages will cause the beam to move to the right on the screen. This control, when turned to the SWEEP position, permits the sawtooth from the sweep circuit oscillator to be amplified by the horizontal amplifier, thus providing horizontal deflection.

g. HOR. GAIN (R129). This control is used as a vernier in connection with the HOR. ATTEN. control to adjust the width of the pattern on the screen in the case of external a-c voltages; and, in the case of d-c voltages, the extent of deflection, either left or right, of the beam. When the HOR. ATTEN. control is in the SWEEP position, the HOR. GAIN control adjusts the width of the sweep.

h. COARSE FREQUENCY (S104). This control selects the range of frequencies of the internal sweep circuit oscillator, which may operate between the limits of 3 and 50,000 cycles. Although the frequency ranges are marked on the panel for convenience of the operator, these frequencies are only approximate; in general, the actual frequency range will be much greater, so that two consecutive frequency ranges will overlap each other.

i. VERNIER FREQUENCY (R158). This control serves as a vernier control of the frequency generated by the sweep circuit oscillator in any one of the six positions of the COARSE FREQUENCY control.

j. SYNC. SELECTOR (S103). This control selects synchronizing voltage for application to the sweep circuit oscillator. The synchronizing voltage may be selected from an external source, from an internal source which provides a portion of the voltage applied to the vertical amplifiers, or from an internal source of line frequency voltage.

k. LOCKING (R154). This control permits selection of either positive or negative peaks of synchronizing voltages and, in addition, controls the amount of locking voltage applied to the sweep circuit oscillator.

l. TERMINALS.

VERTICAL INPUT (AC) (J101). Input for a-c voltages that deflect the beam vertically on the cathode-ray-tube screen.

VERTICAL INPUT (DC) (E102). Input for d-c voltages applied to the vertical amplifiers.

HORIZONTAL INPUT (AC) (E103). Input for a-c voltages that deflect the beam horizontally on the cathode-ray-tube screen.

HORIZONTAL INPUT (DC) (E105). Input for d-c voltages applied to the horizontal amplifiers.

GND. (2) (E101, E104). Direct connection to chassis of equipments and to one side of all other externally applied voltages.

EXT. (E108). Input for external synchronizing voltage to be used in synchronizing the sweep circuit oscillator.

LINE (E106). A source of line supply frequency to be used either in causing deflection for horizontal or vertical input, or as a source of line frequency for any other desired use.

Z AXIS (E107). Connection for an external voltage to be used in intensity-modulating the cathode-ray-tube beam.

TERMINAL BOARD (TB105—Rear Panel). Permits direct connection to either horizontal or vertical deflection plates, and provides a means of beam blanking from internal sweep circuit oscillator. See figure 2 below.

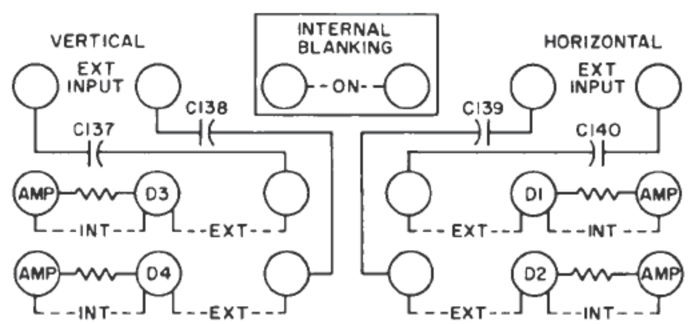


Figure 2. Terminal Board (TB105—Rear Panel)

3. OSCILLOSCOPE OPERATIONAL TECHNIQUES.

a. OBSERVING WAVEFORMS, USING INTERNAL SWEEP AND SYNCHRONIZATION.

Connect the source of alternating voltage (or varying dc) to be observed to the vertical input (AC) and GND connections. Set the COARSE FREQUENCY control (S104) to the slowest sweep frequency, position 3-18. The SYNC. SELECTOR (S103) should be turned to INT., while the LOCKING control (R154) is turned to the zero position. Adjust the VERT. GAIN control (R104) and the VERT. ATTEN. control (S101) for suitable vertical deflection. Adjust the HOR. GAIN control (R129) until the pattern is of the desired width.

When the pattern first appears, it will usually show many cycles of the sine wave under observation. See part A of figure 3 below. Slowly rotate the VERNIER FREQUENCY control (R158) until the number of cycles decrease to the desired number. If the number is still greater than convenient, then the COARSE FREQUENCY control (S104) should be rotated to the next clockwise position; fewer cycles will appear, as shown in part B of figure 3. When the desired number of cycles are obtained, the trace can be locked in by rotating the LOCKING control (R154) either clockwise or counterclockwise, depending upon whether it is desired to lock in with positive or negative synchronizing pulses.

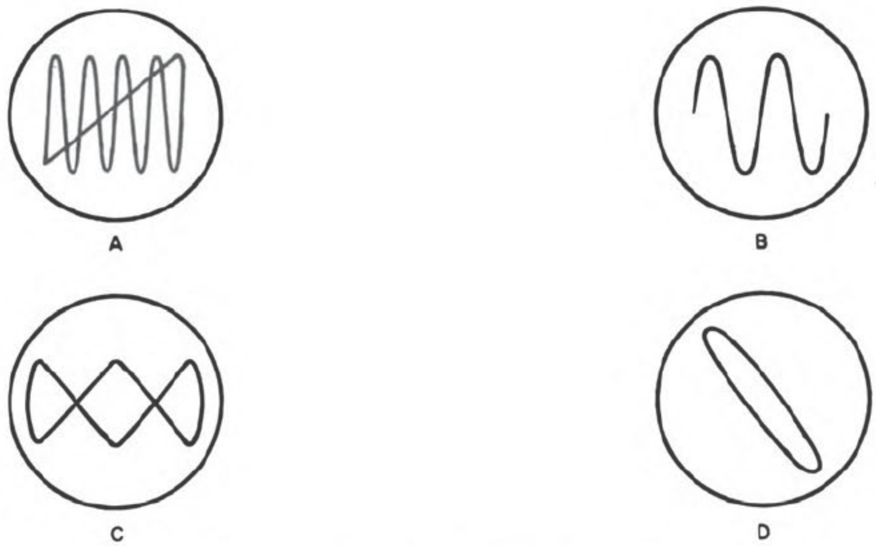


Figure 3. Typical Oscilloscope Presentations

b. OBSERVING WAVEFORMS, USING INTERNAL SWEEP AND EXT. SYNC.

Follow the procedure outlined in the preceding paragraph (3a.), except turn the SYNC. SELECTOR (S103) to EXT. rather than INT., and apply the source of synchronizing voltage between the EXT. binding post and GND.

c. OBSERVING WAVEFORMS, USING INTERNAL SWEEP WITH LINE FREQUENCY SYNCHRONIZING VOLTAGES.

Follow the procedure outlined in paragraph 3(a), except when the sweep circuit is to be locked in at the line frequency, turn the SYNC. SELECTOR (S103) to LINE.

d. OBSERVING WAVEFORMS, USING INTERNAL SINE WAVE LINE FREQUENCY SWEEP.

Connect the source of alternating voltage to be observed between the vertical input (AC) and GND. Set the HOR. ATTEN. control (S102) to the AC divided by 10 position. Make an electrical connection between the LINE

binding post and the horizontal input (AC) binding post. Operate the HOR. GAIN and VERT. GAIN controls to give the desired size of pattern. The LOCKING, VERNIER FREQUENCY, and SYNC. SELECTOR controls have no effect upon the operation.

NOTE

This method provides a quick check on the proper operation of the oscilloscope.

e. OBSERVING LISSAJOUS PATTERNS WITH SINE WAVE VOLTAGES APPLIED TO BOTH HORIZONTAL AND VERTICAL INPUTS.

Connect the two voltages for comparison to the oscilloscope, one to the horizontal input (AC) and the other to the vertical input (AC). Adjust the HOR. ATTEN. and VERT. ATTEN. controls (S102 and S101) to the highest attenuation position that will give suitable deflection in both directions. Adjust the HOR. GAIN and VERT. GAIN controls until the pattern is of the desired size. With the above controls so adjusted, if the two frequencies are exact ratios of each other, definite patterns will result. Two examples of typical pattern arrangements are given in parts C and D of figure 3. Part C illustrates a 3:1 (3, vertical; 1, horizontal) frequency relationship; part D illustrates a 1:1 frequency relationship.

The general rule for determining ratios is to count the number of times the pattern touches one axis and then the number of times it touches the other axis. The ratio between the two is the ratio of the two frequencies. If the beam touches the horizontal axis more often than the vertical axis, then the beam must be moving more slowly in the horizontal direction than it is in the vertical direction. In this case, the lower frequency is being fed to the horizontal amplifier. See figure 4 below. Usually, the horizontal input signal is obtained from a controlled signal source (such as a signal generator), and is used as a reference signal to determine the frequency of the unknown signal applied to the vertical input terminals of the oscilloscope.

Figure 4. Oscilloscope Presentations—Horizontal Frequency Lower than Vertical Frequency

f. VERTICAL DEFLECTION WITH D-C INPUT.

Operate the VERT. ATTEN. control (S101) to the DC position. Apply the d-c voltage to the DC vertical input connection (E102), and adjust the VERT. GAIN control (R104) to give the desired deflection sensitivity.

g. HORIZONTAL DEFLECTION WITH D-C INPUT.

Operate the HOR. ATTEN. control (S102) to the DC position. Apply the d-c voltage to the DC horizontal input connection (E105), and adjust the HOR. GAIN control (R129) to give the desired deflection sensitivity.

h. APPLYING VOLTAGE DIRECTLY TO DEFLECTION PLATES. (In the following discussion, refer to parts A and B of figure 5, below, for location of jumper connections.)

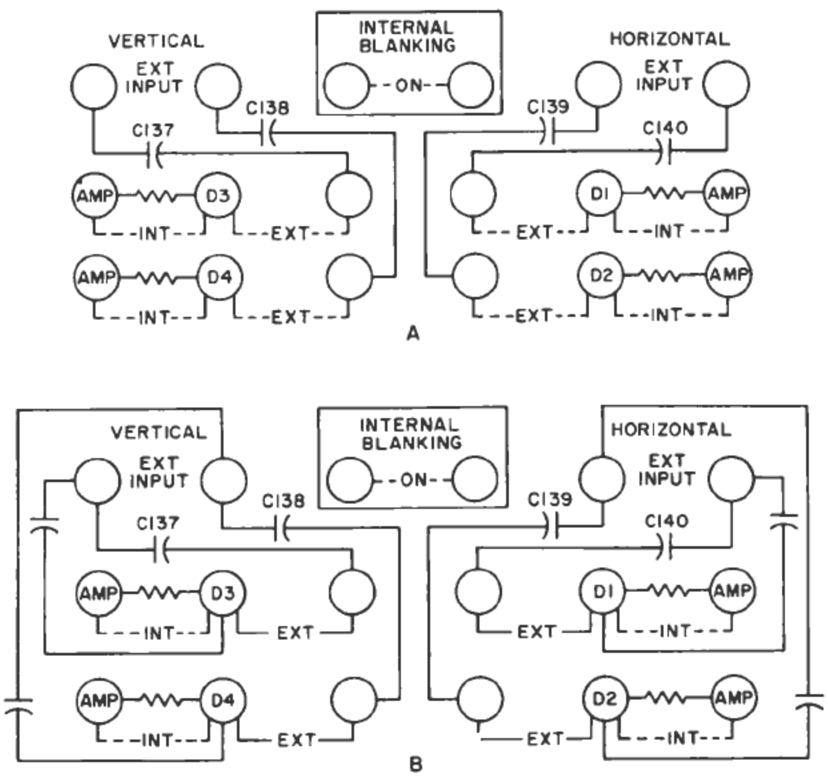


Figure 5. Terminal Board TB105 Connections

(1) Vertical Plates. To apply a voltage directly to the vertical deflection plates, change the jumpers on the vertical side of the board from INT. to EXT. connection, as indicated by the dotted lines on the diagram appearing on the cover of terminal board TB105. The deflecting voltage may then be applied to the two terminals marked EXT. INPUT. These terminals are isolated from the voltage on the deflection plates by capacitors

C137 and C138. In observing very-low-frequency waveforms, the time constant of this input circuit may become objectionable. In this case, larger external capacitors may be connected between the terminals marked EXT. INPUT and the terminals marked D3 and D4, as illustrated in part B of figure 5.

(2) Horizontal Plates. To apply a voltage directly to the horizontal deflection plates, change the jumpers on the horizontal side of the board from INT. to EXT. connection, as indicated by the dotted lines on the diagram appearing on the cover of terminal board TB105. The deflecting voltage may then be applied to the two terminals marked EXT INPUT. These terminals are isolated from the voltage on the deflection plates by capacitors C139 and C140. In observing very-low-frequency waveforms, the time constant of this input circuit may become objectionable. In this case, larger external capacitors may be connected between the terminals marked EXT. INPUT and the terminals marked D1 and D2, as illustrated in part B of figure 5.

i. RETURN TRACE ELIMINATION.

When using the sweep circuit oscillator for horizontal deflection, if it is desired to blank the beam on the return trace, a jumper should be installed between the two INTERNAL BLANKING terminals on terminal board TB105 as illustrated in figure 5. With these terminals connected together, voltage should not be fed in at the Z AXIS binding post (E107) on the main panel. A voltage at the Z axis binding post will distort the sawtooth output of the sweep circuit oscillator, resulting in loss of synchronization.

j. OTHER APPLICATIONS OF THE OSCILLOSCOPE.

In addition to the observation of waveforms as outlined in paragraphs 3a through 3i, the oscilloscope may be used for many other purposes, such as the following:

(1) Alignment of tuned r-f and i-f stages and video circuits.

(2) Alignment of FM discriminator stages.

(3) Observation of irregular waveshapes, pulses, etc.

(4) Approximate measurements of distortion percentage.

(5) Detection and identification of hum in power supplies.

(6) Determination of modulation percentage in transmitters.

(7) Because of the wide frequency response of the vertical amplifiers, which is from zero cycles on dc to 2 mc on ac, the instrument will find extremely wide use in connection with the measurement and observation of waveforms from very low frequencies on up into the high-frequency ranges.

(8) By placing a plastic grid over the face of the oscilloscope, this instrument may be used as an electronic voltmeter. As an example, if it is desired to determine the voltage of an unknown signal being applied,

the VERT. ATTEN. and VERT. GAIN controls (S101 and R104) may be adjusted to give a known deflection, such as 15 small squares, or one and one-half inches. By substituting for the unknown voltage a known voltage of given magnitude, the ratio of the unknown voltage to the number of divisions of deflection of the unknown voltage would be equal to the ratio of the known voltage to the number of divisions of deflection of the known voltage. Thus if, with a given setting of the VERT. ATTEN. and VERT. GAIN controls, the unknown voltage produced 15 divisions and a known voltage of 5 volts produce 5 divisions, as shown in the figure below. The unknown voltage is to 15 as the known voltage (5) is to 5 divisions; therefore, the unknown voltage equals 15 volts.

If either the VERT. ATTEN. control or the VERT. GAIN control (S101 or R104) is changed, recalibration should be effected unless notations of the exact control settings have been made and recorded for future use. Such recorded calibrations should be accurate for relatively long periods of time; they will be affected only by the operator's ability to reset accurately and the potential loss of mutual conductance (with age) of the vertical amplifier tubes.

(9) If a voltage is applied to the d-c vertical amplifier section with unshielded leads, caution should be taken as these leads may pick up stray fields and distort the waveshape being observed. Such precautions consist of using as short leads as possible and orienting the leads so that they do not come close to the source of an a-c field, such as a transformer or alternating-current-carrying wires.

5 VOLTS

UNKNOWN VOLTAGE

THEORY OF OPERATION

1. SUB-FUNCTION BLOCK ANALYSIS.

a. Figure 6, page 31-32, is a functional block diagram of the circuits contained in the TS-O general purpose oscilloscope. The individual circuit groups, as indicated by the blocks, may contain one or more electronic circuits to provide the indicated sub-functional requirement toward a complete operational equipment. A brief description of the purpose of each circuit group of the oscilloscope is given in the following paragraphs.

b. SWEEP OSCILLATOR. The purpose of the sweep oscillator is to generate a sawtooth voltage waveform of selected time duration, to deflect the electron beam of the cathode-ray tube along the horizontal axis. The time duration of this waveform is controlled by the COARSE and VERNIER FREQUENCY controls to provide a relative indication of the frequency and or time duration of applied test voltage waveforms.

c. HORIZONTAL AMPLIFIER. The function of the horizontal amplifier is to amplify or attenuate applied voltage waveforms prior to application to the deflection plates of the cathode-ray-tube indicator. This circuit group contains an input attenuator/selector (HOR. ATTEN.) which selects the internally generated sweep sawtooth voltage from the sweep oscillator, an externally applied a-c waveform, or an externally applied d-c voltage for amplification and resultant application, to control the behavior of the CRT electron beam along the horizontal axis. The excursion of the sweep trace in the horizontal plane is controlled by the HOR. GAIN control. In addition, the horizontal amplifier provides a blanking waveform (if desired) to eliminate the sweep return trace as viewed on the cathode-ray-tube indicator.

d. VERTICAL AMPLIFIER. The vertical amplifier serves to amplify or attenuate applied voltage waveforms prior to application to the vertical deflection plates of the cathode-ray-tube indicator. This circuit group is usually considered to be the input signal channel, as it is used primarily to process the test wave shape or voltage and cause its variations in magnitude to control the vertical position of the cathode-ray-tube electron beam. Since an oscilloscope is basically a device to visually indicate a vectorial relation between amplitude and time, a portion of the signal present at the vertical amplifier is fed to the synchronization channel, for application to the sweep oscillator, to initiate the generation of the sawtooth sweep at some selected voltage level of the input signal. Selection of the input (ac or dc) and variation of the amount of attenuation are accomplished by the VERT. ATTEN. control. The amplitude of the vertical presentation is controlled by the VERT. GAIN control.

e. SYNCHRONIZATION CHANNEL. The purpose of the synchronization channel is to provide a means of synchronizing the sweep oscillator circuits with a selected voltage (EXT., INT., or LINE frequency) so that the horizontal movement of the electron beam will begin at a selected point with respect to the applied synchronizing voltage. This synchronization allows

the presentation on the face of the cathode-ray tube to remain stationary for examination of the signal wave shape applied through the vertical amplifier. Selection of the synchronization source is made by the SYNC. SELECTOR control. The LOCKING control permits selection of either the positive- or negative-going excursion of the selected synchronizing voltage.

f. CATHODE-RAY-TUBE CIRCUITS. The cathode-ray-tube circuits contain the cathode-ray-tube indicator and its associated controls, i.e., INTENSITY and FOCUS. The screen of the CRT displays the effect that applied voltages have on the electron beam generated within the tube.

g. LOW-, INTERMEDIATE-, AND HIGH-VOLTAGE POWER SUPPLIES. The function of these power supplies is to convert the applied a-c line voltage into the required d-c operating potentials for the vacuum-tube circuits of the equipment. The low and intermediate power supplies serve all sections of the oscilloscope except the cathode-ray tube. The high-voltage power supply provides the high negative potential required for accelerating the electron beam of the cathode-ray tube.

2. DETAILED BLOCK ANALYSIS.

a. A detailed equipment block diagram is presented in figure 7, page 31-32, to facilitate an initial understanding of the individual circuits contained in the functional sections of the equipment. Each circuit will be discussed generally as to its purpose, input-output signal connections, and capabilities. Frequent reference should be made to figures 6 and 7 during the discussion. As mentioned previously, the functional and/or detailed block diagrams should be thoroughly understood as to the purpose of the circuits or circuit groups, in order to ensure the proper approach to trouble analysis.

b. SWEEP OSCILLATOR.

(1) This sub-function block contains only one circuit—the sweep circuit oscillator.

(2) Sweep Circuit Oscillator (V108A and B). A type 6J6 tube, V108, is used in a modified multivibrator circuit to generate linear sawtooth voltages for horizontal deflection of the cathode-ray-tube electron beam. The six positions of the COARSE FREQUENCY control and the variable setting of the VERNIER control determine the frequency of sawtooth generation within the range of 3 to 50,000 cycles. The output of the sweep circuit oscillator is coupled to the horizontal attenuator (S102) in the horizontal amplifier.

c. HORIZONTAL AMPLIFIER.

(1) The horizontal amplifier contains the following circuits: horizontal attenuator, horizontal cathode follower, 1st horizontal d-c amplifier, 2nd horizontal d-c amplifier, and intensity modulation amplifier.

(a) Horizontal Attenuator. A-C voltages applied to the horizontal AC input jack may be attenuated by a factor of 1, 10, or 100 by means

of the HOR. ATTEN. control. The amount of attenuation is further controlled by the position of the HOR. GAIN control (fine adjustment). After attenuation, the horizontal a-c input signal is applied to the grid of the horizontal cathode follower. With the HOR. ATTEN. control in the DC position, the connection to the horizontal AC input is removed, and the horizontal DC input jack is connected to the HOR. GAIN control, which can be used to adjust the magnitude of the input before it is applied to the 1st horizontal d-c amplifier (bypassing the horizontal cathode follower). With the HOR. ATTEN. control in the SWEEP position, the sawtooth voltage output from the sweep circuit oscillator is applied to the horizontal cathode follower. The width of the trace which this sawtooth produces can be varied by the HOR. GAIN control.

(b) Horizontal Cathode Follower (V105A). One half of a type 12AT7 tube, V105A, is used as a cathode follower to provide a high-impedance input for externally applied a-c voltage and the internally generated sweep sawtooth. The output voltages from this stage are taken from the low-impedance cathode circuit and attenuated with a low-impedance gain control (HOR. GAIN) before being applied to the 1st horizontal d-c amplifier.

(c) 1st Horizontal D-C Amplifier (V106A and B). A type 12AT7 tube, V106A and B, is used as a direct-coupled paraphase amplifier to amplify the attenuated a-c or d-c inputs from the HOR. ATTEN. control or horizontal cathode follower. When a-c or internal sweep voltages are to be amplified, the input is capacitively coupled from the cathode follower, V105A, thus providing a low-frequency response of one cycle. When serving as d-c amplifiers, the 1st horizontal d-c amplifier circuits obtain the input directly from the HOR. GAIN control. A-C voltages may be applied to the DC input for amplification by the horizontal amplifiers; however, the high-frequency response will be determined by the setting of the HOR. GAIN control. The outputs from this amplifier are directly coupled to, and provide the necessary phase relationships for application to, the 2nd horizontal d-c amplifier. Included in the circuitry of this amplifier is the HORIZ. POS. control.

(d) 2nd Horizontal D-C Amplifier (V107). The 2nd horizontal d-c amplifier is a push-pull circuit which employs a type 6J6 tube, V107. The inputs are direct-coupled from the paraphase amplifier, V106. The plate outputs are connected through terminals D1 and D2 on terminal board TB105 to the horizontal deflection plates of the cathode-ray tube. The over-all high-frequency range of the entire horizontal sweep amplifier system is 500,000 cycles.

(e) Intensity Modulation Amplifier (V105B). One half of a type 12AT7 tube, V105B, is used as an amplifier to amplify external or internal voltages for intensity modulation of the electron beam of the cathode-ray tube. When a jumper is connected between the BLANKING terminals on terminal board TB105, a rectangular voltage pulse of the same time duration as the sweep sawtooth voltage is inverted and amplified by the intensity modulation amplifier. This signal is applied to the grid of the cathode-ray tube, to turn off (blank out) the electron beam during retrace time. When an external signal source is applied to the Z AXIS input jack, it

may be used to intensify or blank the trace at predetermined points, for calibration or testing purposes.

d. VERTICAL AMPLIFIER.

(1) The vertical amplifier contains the following circuits: vertical attenuator, vertical cathode follower, 1st vertical d-c amplifier, and 2nd vertical d-c amplifier. These circuits are similar in operation to the horizontal d-c amplifier circuits.

(a) Vertical Attenuator. A-C voltages applied to the vertical AC input jack may be attenuated by a factor of 1, 10, or 100 by means of the VERT. ATTEN. control. The amount of attenuation is further controlled by the position of the VERT. GAIN control (fine adjustment). After attenuation, the vertical input signal is coupled to the vertical cathode follower. With the VERT. ATTEN. control in the DC position, the connection to the AC input is removed. The DC input jack is connected to the VERT. GAIN control, which can be used to adjust the magnitude of the input signal before it is applied to the 1st vertical d-c amplifier (bypassing the vertical cathode follower).

(b) Vertical Cathode Follower (V101A). One half of a type 12AT7 tube, V101A, is used as a cathode follower to provide a high-impedance input for the attenuated a-c signal voltages. The output voltages from this stage are taken from the low-impedance cathode circuits and attenuated with a low-impedance gain control (VERT. GAIN) before being applied to the 1st vertical d-c amplifier.

(c) 1st Vertical D-C Amplifier (V102A and B). The 1st vertical d-c amplifier is a paraphase amplifier which employs a type 12AT7 tube, V102A and B. When the VERT. ATTEN. control is in its AC signal input positions, the 1st vertical d-c amplifier input is capacitively coupled from the vertical cathode follower, V101A, thus providing a low-frequency response of 5 cycles. When serving as d-c amplifiers, the 1st vertical d-c amplifier circuits obtain the input signal directly from the VERT. GAIN control. A-C voltages may be applied to the DC input for amplification by the vertical amplifiers; however, the high-frequency response will be determined by the setting of the VERT. GAIN control. The outputs from this amplifier are directly coupled to, and provide the necessary phase relationships for application to, the 2nd vertical d-c amplifier. Included in the circuitry of this amplifier is the VERT. POS. control.

(d) 2nd Vertical D-C Amplifier (V103 and V104). Two type 6AH6 tubes, V103 and V104, are used in a push-pull circuit as the final output of the vertical sweep channel. The inputs to these tubes are direct-coupled from the paraphase amplifier. The signal outputs are fed through terminals D3 and D4 of terminal board TB105 to the vertical deflection plates of the cathode-ray tube. The high-frequency response of the entire vertical sweep channel is 2 mc.

e. SYNCHRONIZATION CHANNEL

(1) The synchronization channel is essentially a selector switch and sync amplifier circuit. It serves a very important function in keeping the frequency of the horizontal sweep trace in step with the frequency of the input signal of the vertical sweep channel or with some multiple of this frequency. Without this synchronization, it would be almost impossible to maintain a stable representation of the voltage variations on the screen of the cathode-ray-tube indicator.

(2) Sync Selector-Amplifier (V101B). A three-position SYNC. SELECTOR switch permits the selection of external (EXT.), internal (INT.), or LINE (AC 50-1000 cycles) frequencies to be used in synchronizing the sweep circuit oscillator. External voltages are obtained from connections to the EXT. SYNC. input terminal; line frequencies are taken from a voltage divider connected to a tap in the a-c portion of the power supply; internal sync voltages are derived from a voltage divider in the 2nd vertical d-c amplifier. Voltages selected by the SYNC. SELECTOR are capacitively coupled to one half of a type 12AT7 tube, V101B. The LOCKING control is so connected to the output of the sync amplifier that counterclockwise rotation permits synchronization on the positive peaks of the input sync voltage, and clockwise rotation permits synchronization on the negative peaks of the input sync voltage. The selected voltage peak is capacitively coupled to the sweep circuit oscillator to stabilize its operating frequency.

f. CATHODE-RAY-TUBE CIRCUIT.

(1) The cathode-ray-tube circuit is composed of the cathode-ray tube itself and its related operating controls, i.e., FOCUS and intensity (INT).

(2) A type 3RP1 electrostatic deflection cathode-ray tube, V109, is used as the indicating device. Required operating voltages for accelerating the electron beam are obtained from the high-voltage power supply. Control of the intensity and sharpness of the electron beam is accomplished by including INT. and FOCUS controls in a voltage divider connected to the high-voltage power supply. Deflection voltages from the horizontal and vertical channels are applied to the deflection plates through terminal board TB105. Selection of internal or external (direct) sweep voltages may be accomplished by rearranging the jumpers on TB105.

g. POWER SUPPLY.

(1) The power supply provides low, medium, and high operating potentials for the circuits contained within the oscilloscope. The overall power supply is isolated from the input line voltage by a power transformer, which provides taps to supply the proper voltages to the various rectifiers.

(2) A type 6X4 tube, V110, is connected as a full-wave rectifier to supply d-c voltages for operation of the cathode followers, final amplifier stages, and sweep circuit oscillator. A pair of selenium rectifiers,

CR101 and CR102, are connected as a full-wave rectifier to supply low d-c voltages for the operation of all the other circuits except the cathode-ray tube. A selenium rectifier, CR103, is connected as a half-wave rectifier to supply the high voltage for the cathode-ray tube. Suitable other windings on the power transformer provide heater voltages for all tubes in the instrument. The transformer is fused by means of fuses F101 and F102, which are accessible on the front panel.

3. DETAILED CIRCUIT ANALYSIS.

a. GENERAL.

In the detailed circuit analysis of the TS-O oscilloscope, the circuits will be approached in the same order as they were in the functional and detailed block analysis. Attention should be directed not only to the partial schematic drawings during the circuit discussion, but also to the over-all schematic diagram, figure 18, pages 51, 52.

b. SWEEP OSCILLATOR.

(1) Sweep Circuit Oscillator (V108). The sweep circuit oscillator circuit arrangement is illustrated in figure 8, page 33-34. V108 is a cathode-coupled multivibrator circuit, employed as a horizontal sawtooth oscillator, which can be operated over six frequency ranges to provide any frequency from 3 to 50,000 cycles per second. The desired frequency range is selected by the COARSE FREQUENCY switch, S104, utilizing capacitors C125 through C131. These capacitors, as selected in the six positions of S104, act alternately (and respectively) as sawtooth-generating capacitors for the second triode section, V108B, and as coupling capacitors from the first triode section, V108A, to the second triode section of the multivibrator. The switch position shown in figure 8 utilizes C130 as the sweep charging capacitor and C131 as the multivibrator coupling capacitor.

(a) Fine frequency control is accomplished by means of the dual VERNIER FREQUENCY potentiometer, R158A and B, in the plate and grid of triode section B of the multivibrator. As indicated by the dotted line, both potentiometers are on the same shaft and rotate concurrently.

(b) The cathode-coupled multivibrator is of the free-running type, which depends upon the time constants of the coupling circuits and the operational supply voltage to determine its frequency of oscillation. Thus, the frequency is determined by the values of C131 and R160 and the setting of the VERNIER CONTROL, R158B (see figure 8). In addition, the other portion of the VERNIER CONTROL, R158A, varies the plate voltage on V108B to provide further frequency control. The circuit operates as a standard cathode-coupled multivibrator wherein the A section is cut off while the B section is conducting, and vice versa. A sawtooth waveform is obtained from the B plate by connecting a capacitor from plate to ground (C130 in figure 8). C130 charges toward B+ when the B section is in its cutoff condition, providing the proper sawtooth. When the B section conducts, the plate voltage drops, and the capacitor discharges through the conduction path of the tube.

(c) The synchronizing signal from the LOCKING control, R154, is applied to the grid (pin 5) of V108A through isolation resistor R162. This causes the frequency of the multivibrator to lock in at the frequency of the synchronizing signal or some submultiple thereof.

(d) The sawtooth output is taken from plate B (pin 1) of V108 through a frequency-compensated voltage divider consisting of R155 shunted by C123 and C142 and R125 shunted by C113. C124 serves as a coupling capacitor. C113 and R125 are physically located on the HOR. ATTEN. control, S102, which, in the SWEEP position, connects the sawtooth signal to the grid of the horizontal cathode follower, V105A. The high-frequency linearity of the sawtooth wave shape may be adjusted by means of C123, which is a maintenance adjustment. B+ for sweep oscillator V108 is provided by the HOR. ATTEN. control, S102, and is removed in all positions when internal sweep is not required, i.e., for a-c horizontal input and d-c horizontal input.

(e) Bias for the multivibrator is supplied by cathode resistor R161. The waveform at the cathode consists of rectangular pulses having the same duration as the retrace time and having the proper phase. These pulses may be jumpered at terminal board TB105, to be applied to the input of the intensity modulation amplifier and thus provide return-trace elimination on the cathode-ray tube when using the sweep circuit oscillator.

c. HORIZONTAL AMPLIFIER.

(1) Horizontal Input Attenuator (S102). A schematic diagram of the horizontal input attenuator is presented in figure 9, page 35-36. This switch (S102) serves a dual purpose: namely, the selection of the signal to be amplified by the horizontal sweep amplifier section and the attenuation of a-c signals applied to the HOR. INPUT binding post, E103, except for position AC-1. Any a-c voltage which is impressed between the horizontal input (AC) and GND is applied through capacitor C110 to the three-element horizontal attenuator network. This network consists of resistor R126 shunted by C114 with C111 in series and resistor R127 shunted by C115 with C112 in series. The network is so designed that it is non-frequency discriminating up to square-wave frequencies of 25 kc. On positions 10 and 100, the applied voltage is reduced by a factor of approximately 10 and 100, respectively. On position 1, the voltage impressed is applied directly to the grid (pin 2) of the horizontal cathode follower, V105A. When the HOR. ATTEN. control, S102, is rotated to the DC position and a d-c or a-c voltage is impressed between the HOR input (DC), E105, and GND, the voltage is controlled by potentiometer R129A, the DC HOR. GAIN control, and applied to the grid (pin 2) of the 1st horizontal d-c amplifier, V106A. When switch S102 is in the SWEEP position, the internal sawtooth oscillator is activated (B+ is supplied by S102 contacts), and its resultant sawtooth voltage is fed to the grid (pin 2) of the horizontal cathode follower, V105A. R125 and C113 make up a portion of the voltage divider from the sweep oscillator circuit.

(a) C111 and C112 are maintenance adjustments which provide a degree of frequency compensation at the high end of the response range.

At 25 kc and above, these adjustments can be adjusted to provide a more nearly perfect representation of the input wave shape.

(2) Horizontal Cathode Follower (V105A). The operation of the horizontal cathode follower is closely tied in with the action of S102, the HOR. ATTEN. switch; therefore, its circuit arrangement is included with S102 in figure 9. One half of a 12AT7 tube, V105A, is connected in a conventional cathode-follower circuit arrangement. The function of a cathode-follower circuit is to match a low-impedance load to a high-impedance source, and to isolate critical circuits from loading effects. Basically, a cathode follower is similar to an R-C coupled amplifier, except that the output is taken from the cathode circuit instead of the plate. The output signal is in phase with the input, and has a slightly reduced amplitude.

(a) The output signal is taken from the top of biasing resistor R132, coupled through C116, and developed across the A.C. HOR. GAIN control, R129B, which allows the amplitude of the signal applied to the following stage to be adjusted. Due to the fact that R129B and C116 have low impedances, the circuit capacitances will be negligible and frequencies of one cycle to 500 kc may be controlled by R129B without frequency discrimination. The output voltage of R129B is taken through the HOR. ATTEN. control, S102, and applied to the grid (pin 2) of the first horizontal d-c amplifier, V106A.

(b) The output signal of the cathode follower will not be distorted unless the applied signal is of great enough amplitude to cut off the plate current of the tube on negative alternations of the input cycle. The degenerative effect of the unbypassed cathode resistor almost eliminates the possibility of grid current due to a positive input. As a result of this feature, the circuit has a high input impedance. R130 acts as a parasitic suppressor to suppress oscillations.

(3) 1st Horizontal D-C Amplifier (V106). The horizontal amplifiers are shown in figure 10, page 37-38. This illustration presents the entire amplifier section to show the method of coupling employed. V106 is the 1st d-c amplifier and will be discussed as to its circuit function. A postion of the HOR. ATTEN. control, S102, has been included to permit a tie-in with the previous portion of the section.

(a) V106 is a type 12AT7 tube which serves as the 1st horizontal d-c amplifier. It is in essence a frequency-selective paraphase amplifier, which will be explained more fully later under this heading. When the circuit is amplifying a-c voltages or the internally generated sawtooth sweep, the signal is applied to the grid (pin 2) of V106A from the center arm of the low-impedance gain control, R129B, through switch S102. In all AC positions of the switch, the cathode resistor, R134, of V106A is bypassed by C118 to eliminate degeneration. B+ for tube V106 is supplied through balanced resistors, R139 for the A section and R140 for the B section. Under low-frequency signal input conditions C119 has a high reactance, resulting in a very small signal being fed to V106B; therefore, V106A is the only portion of V106 which processes the signal. Its output is direct-coupled through R143 to the grid of V107A, the second d-c amplifier.

(b) The operation of V106 as a paraphase amplifier is similar to a two-tube phase inverter. It should be recalled that this tube depends on a voltage-divider network for proper operation. The coupling from V106A to V106B is controlled by the reactance of C119. At high frequencies, because of the low reactance of C119, a portion of the signal is coupled to the grid (pin 7) of V106B. R187 and R138 provide a voltage-divider network to balance the triodes of V106. The output of V106A is direct-coupled through R143 to the grid (pin 6) of V107A, while the output of V106B is direct-coupled through R144 to the grid (pin 5) of V107B. C119 is a maintenance adjustment which is set to provide the amplifiers with proper high-frequency response.

(c) The bias for V106B is adjusted by the setting of the HOR. POS. control, R136. This controls the conduction of V106B and the resultant d-c voltage applied to the grid of V107B, to position the beam horizontally on the cathode-ray-tube screen.

(d) When the circuit is amplifying d-c voltages, the signal is applied to the grid (pin 2) of V106A from the center arm of the high-impedance gain control, R129A, through S102. In this position there is a slight negative contact potential developed on pin 2 (V106A) because of the high input impedance of the circuit. This condition is cancelled out by selection of a positive potential by the HOR. D.C. BAL. control, R135, which is in series with R133. Improper adjustment of R135 will result in a shift of the electron beam with various settings of the HOR. GAIN control, R129A. Proper adjustment of the HOR. D.C. BAL. control is made when rotation of the HOR. GAIN control has no effect on the position of the horizontal trace. When the circuit is amplifying d-c voltages, the cathode bias resistor, R134, is left unbypassed to eliminate low-frequency discrimination.

(4) <u>2nd Horizontal D-C Amplifier (V107)</u>. The 2nd horizontal d-c amplifier uses a type 6J6 tube whose sections are connected in push-pull, as illustrated in figure 10, page 37-38. The advantages of having this output stage designed as a push-pull amplifier are more positive control of the electron beam and greater stability of the wave shape presentation with variations in power supply voltages.

(a) The output from the 1st horizontal d-c amplifier, V106, is applied to the grids (pins 5 and 6) of V107, through resistors R143 and R144. These resistors act to suppress any tendency for spurious oscillation that may occur. They perform this function by counteracting any grid current that would be produced by oscillation within the stage. The cathode of V107 is biased to ground through resistors R142 and R141 (BIAS ADJ.) in series. When the circuit is in operation, the grids of V107 are approximately 70 volts above ground due to the direct coupling from V106. Resistors R142 and R141 must provide sufficient voltage drop to properly bias both sections of V107; this voltage is approximately +75 volts under normal operating conditions. The B+ voltage is supplied to the plates (pins 1 and 2) of V107, through plate load resistors R145 and R146. The resultant output signals from the plates are directly coupled to the horizontal deflection plates of the cathode-ray tube through terminal board TB105.

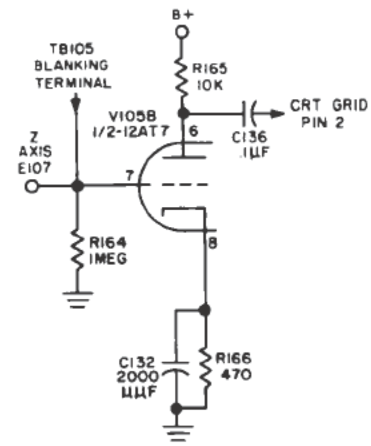
(b) In order to visualize the complete amplifier operation, a signal should be traced through the amplifier chain of V106 and V107. Considering again a low-frequency input signal, the path of the signal will be through one side of the 1st d-c amplifier, V106A. After amplification, the signal is applied through suppression resistor R143 to the grid (pin 6) of V107A. The signal will cause a variation in plate current in this half of the tube; since both halves (V107A and B) have a common cathode circuit, the signal is impressed upon the B section of V107. Assigning polarities to a signal, the action is as follows: With a positive-going signal on the grid (pin 6) of V107A, tube current will increase. As the current increases the voltage at the cathode (pin 7) will rise. Since the grid (pin 5) of V107B is at a stationary potential (determined by the setting of the HOR. POS. control, R136) as far as the signal is concerned, the rising cathode voltage causes V107B to reduce its tube current, thereby accomplishing a push-pull input-output condition for the output stage, V107. When a high-frequency signal is applied to V106, both sections of this tube amplify the signal because of the lower reactance of C119. At higher frequencies, C119 allows sufficient signal to be applied to the grid (pin 7) of V106B to allow it to conduct. The two triode sections provide signals of the proper phase to V107A and B for push-pull operation.

(c) BIAS ADJUST control R141 is provided so that compensation for tolerances in resistors and electron tubes may be made, in order to maintain the proper bias on the final stage. Normally, this control will not have to be adjusted unless tubes V106 and V107 are changed, in which case adjustment should be minor. Proper adjustment of R141 is obtained when the voltage drop across plate load resistor R145 or R146 is 90 volts with the electron beam horizontally centered on the cathode-ray tube.

(d) Since the amplifier circuit is designed to operate in push-pull, any power supply variation caused by fluctuating line voltage has essentially no effect on the center of the beam of the cathode-ray tube, as a voltage change on one plate is accompanied by an equal voltage change on the other plate. This feature allows the grid screen overlay markings to be used as reference points for time measurements.

(5) Intensity Modulation Amplifier (V105B). The intensity modulation amplifier circuit arrangement is illustrated in figure 11, page 21. This circuit serves as both a blanking amplifier and a modulation amplifier. Prior to explaining the action of the circuit, it is necessary to discuss this concept of modulation. In cathode-ray-oscilloscope terminology modulation of (change in) the intensity of the cathode-ray-tube beam is known as Z axis modulation. Such modulation is often useful to establish a time base for the horizontal deflection of the cathode-ray-tube beam. As an example, the beam might be modulated by a 1000-cycle source, which would cause it to increase and decrease in brilliance every one-thousandth second or every one thousand microseconds. With this intensity modulation superimposed upon an observed waveform, the duration of the waveform could be calculated.

(a) One half of a type 12AT7 tube, V105B, is utilized as an amplifier to provide blanking or intensity modulation for the cathode-ray-tube beam. Input voltages to this amplifier are obtained from the blanking terminal on rear terminal board TB105 or from the Z AXIS input jack. When



V105B (12AT7) TABLE OF VOLTAGES AND RESISTANCES

ELEMENT	PIN NO.	VOLTAGE	RESISTANCE
PLATE	6	+77V	80K
GRID	7	+.7V	470
CATHODE	8	+1.4V	470

Figure 11. Intensity Modulation Amplifier

the input voltage is taken from the blanking terminal (TB105), rectangular pulses from the cathode of the sweep circuit oscillator are directly coupled to the grid (pin 7) of V105B. Direct-coupling of this signal eliminates the possibility of low-frequency distortion. The positive-going portion of the rectangular pulse causes the amplifier to conduct, thus reducing the plate voltage and producing a negative-going signal. This negative pulse is coupled through C136 to the control grid of the cathode-ray tube; its amplitude is sufficient to cut off the electron beam and thus keep the scope face blank during the retrace time interval. Should the input signal be taken from the Z **AXIS** input jack, it too is directly coupled to the grid of V105B. Positive input signals will blank the electron beam, while negative signals will intensify (brighten) the trace on the cathode-ray-tube screen.

(b) Resistor R164 acts as a grid return to ground. Bias for the amplifier is provided in the cathode circuit by resistor R166 shunted by capacitor C132. This resistor-capacitor combination provides compensation for improving the high-frequency response of the amplifier. The B+ is supplied to the plate through resistor R165, and the output is taken from the plate through capacitor C136 and applied directly to the control grid of the cathode-ray tube, V109.

d. VERTICAL AMPLIFIER.

(1) <u>Vertical Input Attenuator (S101)</u>. A schematic diagram of the vertical input attenuator is presented in figure 12, page 39-40. S101 serves a dual purpose: it selects the signal to be amplified by the vertical sweep amplifier section, and except for the AC-1 position, it selects a fixed amount of attenuation for a-c signals applied to the VERT. INPUT jack. Any a-c voltage which is impressed between the vertical input (AC) and GND is applied through capacitor C106 to the three-element vertical attenuator network. This network consists of resistor R102 shunted by C103 with C101 in series, and resistor R103 shunted by C104 with C102 in series. The network is so designed that it is non-frequency-discriminating up to square-wave frequen-

cies of 100 kc. On positions 10 and 100, the applied voltage is reduced by a factor of approximately 10 and 100, respectively. When the VERT. ATTEN. control, S101, is rotated to the DC position and a d-c or a-c voltage is impressed between the vertical input (DC) and GND, the voltage is controlled by potentiometer R104A, the DC VERT. GAIN control, and is applied to pin 2 of the 1st vertical d-c amplifier, V102A through a portion of S101. R104 serves as a portion of the input voltage divider network when S101 is in the DC position.

(a) C101 and C102 are maintenance adjustments to provide some degree of frequency compensation at the high end of the response range. At 100 kilocycles and above, these adjustments can be adjusted to provide a more nearly perfect representation of the input wave shape.

(2) Vertical Cathode Follower (V101A). The operation of the vertical cathode follower is closely tied in with the action of S101, the VERT. ATTEN. switch; therefore, its circuit arrangement is included with S101 in figure 12, page 39-40. One half of a 12AT7 tube, V101A, is connected in a conventional cathode-follower circuit arrangement. Like the horizontal cathode follower, this stage serves to provide an impedance match between the high-impedance input and the low-impedance output, which is required by the direct-coupled amplifier stages. As in any test instrument, the input circuitry to the test device must have a high impedance to reduce the possibility of loading, which would distort the true operating conditions of the circuit under test.

(a) The signal is taken from the top of biasing resistor R107, coupled through C106 and developed across the A.C. VERT. GAIN control, R104B, which adjusts the amplitude of the signal applied to the following stages. Since C106 and R104B have low impedances, the circuit capacitances will be negligible, and voltages having frequencies of 5 cycles to 2 mc may be attenuated by R104B without frequency discrimination. The output voltage, as selected by R104B, is fed through the VERT. ATTEN. switch, S101, to the grid, (pin 2) of the 1st vertical d-c amplifier, V102A.

(b) Plate voltage for V101A is obtained from the low-voltage power supply, and is decoupled by C134D and C107 to prevent any a-c variations from affecting other stages tied to the same power source. The stage (like the horizontal cathode follower) is protected from the possibility of parasitic oscillations by grid limiting resistor R105.

(3) 1st Vertical D-C Amplifier (V102). The vertical amplifiers are illustrated schematically in figure 13, page 41-42. Even though the vertical amplifiers are similar in operation to the amplifiers in the horizontal channel, they will be discussed in detail.

(a) V102 is a type 12AT7 tube which serves as the 1st vertical d-c amplifier. As in the case of the horizontal d-c amplifier, it is a frequency-selective paraphase amplifier. When a-c voltages are amplified, the signal is applied to the grid (pin 2) of V102A from the center arm of the low-impedance gain control, R104B, through switch S101. The

resistance of R104B is low so as to afford no frequency discrimination; therefore, the position of the gain control has no effect on the bandwidth in the AC attenuator positions. In all AC positions, cathode resistor R110 is bypassed by C108 to eliminate degeneration. B+ for tube V102 is supplied through balanced resistors R116 and R117. Under low-frequency signal input conditions, V102A is the only portion of V102 which processes the signal. Its output is direct-coupled through R115 to the grid (pin 1) of V103, one half of the push-pull 2nd d-c amplifier.

(b) The coupling from V102A to V102B is controlled by the reactance of C109. At high input frequencies a portion of the signal on the plate of V102A is fed to pin 7 of V102B because of the lowered reactance of C109. This high-frequency signal is amplified by V102B to provide additional high-frequency boost before application to the other half of the 2nd d-c amplifier, V104. At this time, V102 is acting as a paraphase amplifier to provide out-of-phase signals to the push-pull output stage. Resistors R189 and R111, together, form a voltage divider network that balances both triodes of V102 for proper vertical centering. C109 is a maintenance adjustment which is set to provide the amplifiers with the proper high-frequency response.

(c) The bias for V102B is adjusted by the setting of the VERT. POS. control, R111. This controls the conduction of V102B and, therefore, the d-c voltage which is applied to the grid of V104.

(d) When d-c voltages are amplified, the signal is applied to the grid (pin 2) of V102A from the center arm of the high-impedance gain control, R104A, through switch S101. Since the resistance of R104A is high (2 megohms), the position of the wiper arm will affect the frequency characteristics of the amplifier. It can vary as much as 300 kc to 3 mc, depending on the wiper arm location. The VERT. D.C. BAL. control (R112) is included in the circuit to provide cancellation of any negative contact potential on the grid of V102A when S101 is in the DC selector position. This control is adjusted in a manner similar to that of the HOR. D.C. BAL. control. The cathode bias resistor, R110, is left unbypassed when d-c input signals are amplified, to allow passage of the low-frequency components.

(4) <u>2nd Vertical D-C Amplifier (V103 and V104).</u> The 2nd vertical d-c amplifier is a push-pull stage which employs two type 6AH6 tubes, V103 and V104. During the following discussion refer again to figure 13, page 41-42.

(a) The output from the 1st vertical d-c amplifier is applied to the grids (pins 1) of V103 and V104, which constitute the second push-pull amplifier, through resistors R115 and R118. These resistors act to suppress any tendency for spurious oscillation. The cathodes of V103 and V104 are tied together and obtain their bias voltage from paralleled resistors R190 and R120 in series with the BIAS ADJ. control, R119. Since the grids of V103 and V104 are approximately 80 volts above ground, because of the direct connection from the previous stage, the cathode must develop a voltage slightly higher than this to supply sufficient operating bias.

The B+ voltage is supplied to the plates (pins 5) of V103 and V104, through plate load resistors R123 and R124. The screen grids (pins 6) of V103 and V104 are tied together and supplied with voltage through a common screen dropping resistor, R122, shunted by the LINEARITY control, R121. Since these tubes operate in push-pull, there is no need to bypass the screens. The suppressor grids (pins 2) of V103 and V104 are tied to the cathode, as in a normal pentode amplifier when the cathode is operated above ground. The output signal is directly coupled from the plates (pins 5) of the final push-pull amplifier stages to the deflection plates of the cathode-ray tube, through terminal board TB105.

(b) When a low-frequency signal is applied to the amplifier stages, the following circuit action occurs: The signal is amplified by V102A and applied to the grid (pin 1) of V103. The signal produces a change in plate current in this tube. As a result of the common cathode connection between V103 and V104, the signal is also impressed upon the circuit of V104. Assigning polarities to the signal, a positive-going signal on the grid (pin 1) of V103 causes the plate and cathode current to increase. As the current increases, the voltage at the common cathode connection (pins 7 of V103 and V104) increases. The grid (pin 1) of V104 is maintained at a constant voltage level by V102B, as determined by the setting of R111, the VERT. POS. control. The rise in cathode voltage reduces the current through V104, thus causing its plate potential to rise at a rate determined by the rise in cathode potential. Therefore, the resultant voltages as seen at the plates of V103 and V104 are of opposite phase, as required for push-pull operation.

(c) When V102B amplifies any high-frequency signal impressed upon its grid through C109, the signal is inverted and applied through R118 to the grid (pin 1) of V104, in addition to the signal impressed on the common cathode connection of V103-V104. This type of arrangement provides sufficient high-frequency boost to obtain the upper limit (2 mc) of the amplifier bandpass.

(d) The BIAS ADJUST control, R119, is provided so that compensation for tolerances in resistors and electron tubes may be made, in order to maintain the proper bias on the final stage. Proper adjustment of R119 is obtained when the voltage drop across plate load resistor R123 or R124 is 45 volts with the electron beam vertically centered on the cathode-ray tube. The LINEARITY adjustment, R121, is incorporated in the circuit to adjust the voltage on the screens of the final push-pull stage, in order to maintain maximum linearity with changes in tubes or component aging. The LINEARITY control is adjusted to provide an undistorted vertical presentation, regardless of the trace placement (vertically) on the screen of the cathode-ray tube. Normally, these controls will not have to be adjusted unless tubes V102, V103, and V104 are changed, in which case the adjustments will be minor.

e. SYNCHRONIZATION CHANNEL.

(1) SYNC. SELECTOR Switch (S103). The sync selector-amplifier circuit is shown in figure 14, page 43-44. The purpose of the SYNC. SELECTOR switch,

S103, is to provide a means of selecting external (EXT.), internal (INT.), or line (LINE) frequency voltages to permit synchronization of the sweep circuit oscillator. The signal from the SYNC. SELECTOR switch is fed through capacitor C121 to the grid (pin 7) of V101B.

(a) Line-frequency voltage is supplied from the filament winding of the power supply through a voltage divider consisting of R148 and R149.

(b) External synchronizing voltages are applied to binding post E108.

(c) Internal frequency voltage is supplied from the low-impedance cathode circuit of the 2nd vertical d-c amplifier (V103 and V104), through decoupling resistor R108.

(2) Sync Amplifier (V101B). One half of a type 12AT7 tube, V101B, is used as the sync amplifier. The stage is a conventional amplifier, except that the LOCKING control, R154, is placed across the plate-to-cathode connection of the tube. The LOCKING control permits the synchronization of the sweep circuit oscillator from either positive or negative peaks of the applied synchronization voltage.

(a) The grid of the sync amplifier, V101B, is returned to the junction of R153 and R152 through resistor R151, to provide proper bias for the stage. Plate voltage for V101B is obtained from a voltage divider, consisting of a portion of R154 in series with plate load resistor R150, connected to the low-voltage power supply.

(b) Examination of the circuits between the plate of V101B and ground will reveal that, with a signal applied to the control grid, the voltage at the high-potential end of the LOCKING control, R154, will vary with the signals developed at the plate of this tube, and the voltage at the low-potential end of the control will vary with the signals developed at the cathode. The output signal from the sync amplifier is dependent upon the wiper arm position of R154. When this control is at approximately the center of its rotation, there is no output signal, since the electrical center of the control is grounded. However, rotation of the LOCKING control toward the cathode side of R154 results in an output signal which is in phase with the grid signal, while rotation toward the plate side results in an output which is out of phase with the grid signal. Thus the LOCKING control may be used to lock-in the sweep circuit oscillator with either the positive or negative peak of the synchronizing voltage.

(c) The sync voltage of the polarity selected is coupled through C122 and isolation resistor R162 to the grid (pin 5) of V108A, the sweep circuit oscillator, to initiate the horizontal sweep at the desired point.

f. CATHODE-RAY-TUBE CIRCUIT.

(1) Figure 15, page 45-46, presents the schematic diagram of the cathode-ray tube circuit. A type 3RP1 cathode-ray tube, V109, is used as the indicating medium for the oscilloscope. This tube utilizes electrostatic deflection and has four deflection plates, with connections directly from the plates to the tube socket. Voltage for the operation of V109 is obtained from the high-voltage section of the power supply.

(a) Both positive and negative voltages are applied to the electron gun components of the CRT to accelerate and control the electron beam. A negative potential, approximately —550 volts, is obtained from the high-voltage power supply; it is applied to one side of the filament (pin 1), and through R179 to the control grid (pin 2) of V109. A voltage-divider network consisting of R176 (INTENSITY control), R177 (FOCUS control), and R178 is connected between the negative high-voltage supply and ground. The cathode (pin 3) of V109 is connected to the center arm of the INTENSITY control, R176, through resistor R180. As the INTENSITY control is rotated, it varies the potential difference between the cathode of V109 and the control grid, thereby controlling the intensity of the beam. Referring to figure 15, page 45-46, as the center arm of the INTENSITY control, R176, is moved toward ground, the cathode is made more positive, thus increasing the bias (reducing the intensity) on the CRT. The FOCUS control, R177, is returned to ground through R178, and serves to focus the cathode-ray-tube beam by varying the potential on the focus anode of the cathode-ray tube. Pin 8 of V109, and the connection to the accelerating anode, grid 2, receives a positive voltage from a voltage divider, R181 and R182. The voltage at the junction of R181 and R182 determines the astigmatic focus, and is designed to be equal to the nominal d-c voltage of the deflection plates (pins 6, 7, 9, and 10) of V109.

(b) The vertical and horizontal deflection plates (pins 6, 7, 9, and 10, respectively) are directly connected to terminal board TB105. When jumpers on this terminal board are arranged for internal connection, the output leads from the vertical and horizontal amplifiers are connected directly to the deflection plates. When the jumpers are arranged for external connection, the output leads from the vertical and horizontal amplifiers are connected to the deflection plates through resistors R183 to R186 inclusive. These resistors provide the d-c positioning voltages that are present with the internal connection; however, no signal from the amplifiers is impressed upon the deflection plates. The external direct signal may be applied to the deflection plates through capacitors C137 to C140 inclusive by connecting the external signal to the terminals marked EXT. INPUT. If it is desired to use an external capacitor to couple the signal directly to the deflection plates, this capacitor may be connected to the terminals marked D1 through D4 on the terminal board.

(c) As explained previously, when a jumper is connected across the terminals marked INTERNAL BLANKING on TB105, the blanking pulse is connected to V105B, the intensity modulation amplifier. The resultant output of this stage is coupled through C136 to the grid (pin 2), of V109.

A negative-going pulse on this grid increases the bias during the pulse period, to prevent the electron beam from reaching the screen; thus, the retrace is blanked out. If a signal is fed into the Z AXIS input to V105B, either blanking (negative-going signal at grid 2 of V109) or intensification (positive-going signal at grid 2 of V109) of the electron beam can be accomplished.

g. POWER SUPPLY.

(1) The power-supply circuit schematic is presented in figure 16, page 47-48. All voltages for operation of the oscilloscipe are obtained from the power supply, utilizing transformer T101. The primary of this transformer is connected to the permanent a-c power cable, W103. Fuses F101 and F102 are used between the input and the primary. The POWER OFF-ON switch, S105, is connected in series with one fuse and one side of the primary. The secondary windings of T101 provide the appropriate a-c voltage to rectifiers, which produce the low, medium, and high d-c voltages required by the circuits of the equipment.

(a) There are basically four secondary windings on transformer T101. One of these is center-tapped to ground and provides two full-wave voltages, approximately 100 and 320 volts, on each side of the center tap. The 320-volt winding is connected to the plates (pins 1 and 6) of the intermediate voltage rectifier, V110. The output is taken from the cathode (pin 7) of this rectifier, and is suitably filtered by means of capacitors C135A and C135B, in conjunction with resistor R171, to provide B+ voltage for the final stages of the horizontal amplifier. This output is also decoupled by means of resistors R172 and R173 and capacitor C135C, and is supplied as the B+ voltage for the final stage of the vertical amplifiers. The B+ voltages for the vertical and horizontal cathode followers are provided by the decoupling networks consisting of R175 and C134D, and R174 and C134C, respectively.

(b) The 100-volt winding is connected to the anode terminal of CR101 and CR102 through protective resistors R167 and R168. The output from these selenium rectifiers is filtered by C134A and C134B, in conjunction with R170, to provide low-voltage B+ supply for the intensity modulation amplifier and the 1st d-c horizontal and vertical amplifiers.

(c) Another secondary winding has its low-voltage side connected to one side of the 320 volt winding, and its high-voltage side connected to the cathode of selenium rectifier CR103. The output from this rectifier is filtered by C133A and C133B, in conjunction with R169, and is used as the high negative voltage for the cathode-ray tube.

(d) A separate 6.3-volt winding, (terminals Y-Y) is used to supply the heater of the cathode-ray tube, V109. Another 6.3-volt winding (terminals X-X), which is center-taped to ground, is used to supply the heaters of all other tubes in the equipment.

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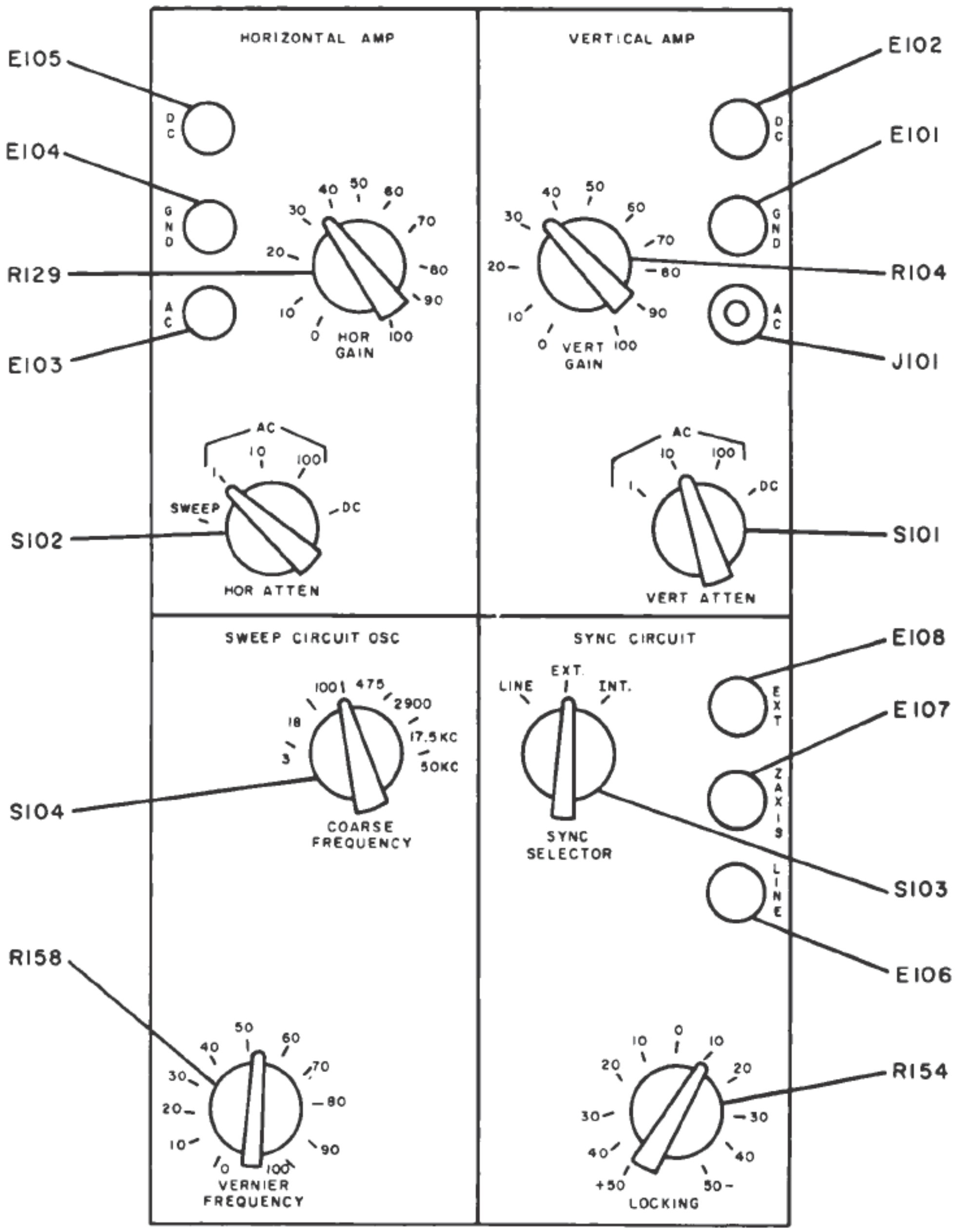


B.
TOP PANEL VIEW

Figure 1. Panel Connectors and Controls

778-958 O - 65 (Follows text) No. 1

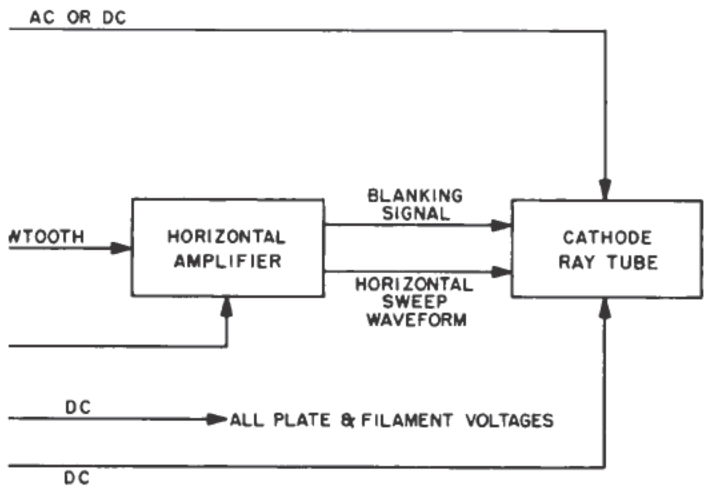


Figure 6. Functional Block Diagram of TS-O Oscilloscope

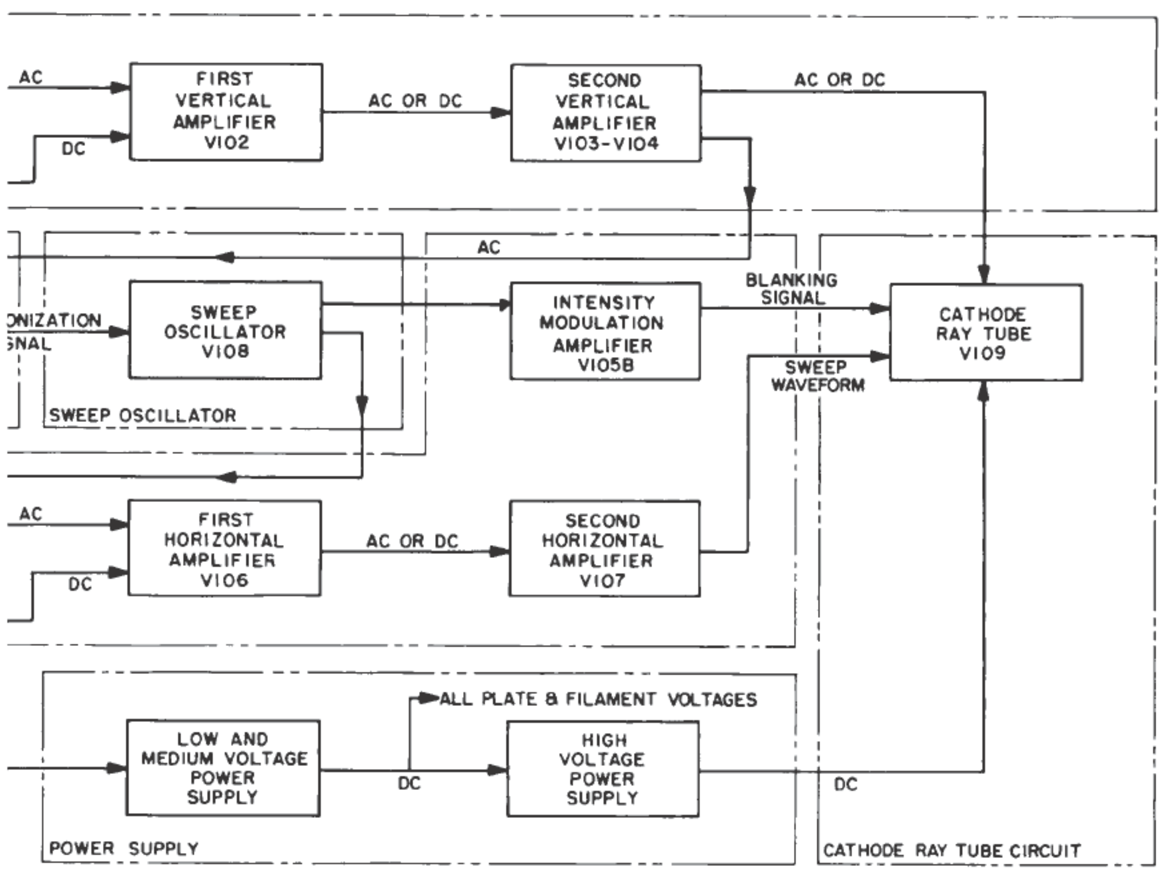
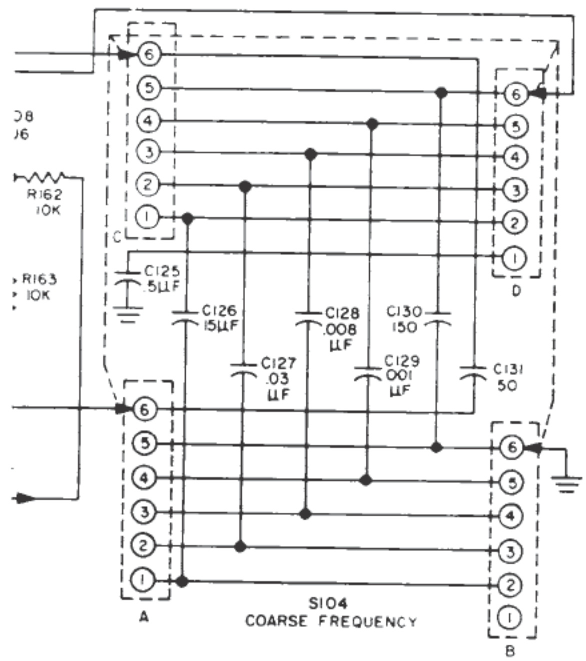


Figure 7. Detailed Block Diagram of TS-O Oscilloscope

778-958 O - 65 (Follows text) No. 2



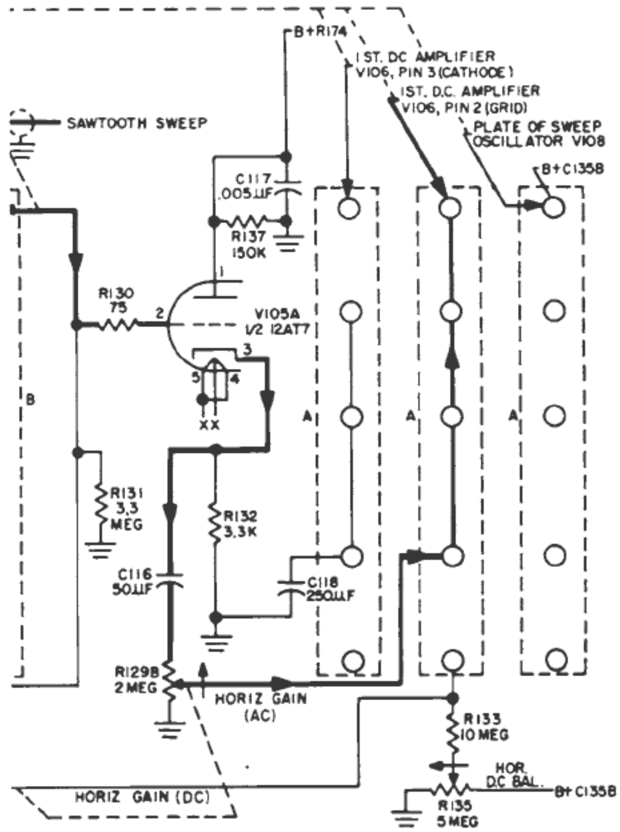
TAGES AND RESISTANCES

VOLTAGE	RESISTANCE
+30V	6M
+35V	300K
3.15VAC	0
3.15VAC	0
0V	10K
−8V	1M
+0.8V	470

ONTROL SET AT POSITION 3,
NIER CONTROL SET AT 0
TROL SET AT INT.
T AT +50

weep Oscillator

778-958 O - 65 (Follows text) No. 3



.TAGES AND RESISTANCES

VOLTAGE	RESISTANCE
+112V	100K
0V	200K
+2.2V	3.3K
3.15VAC	0
3.15VAC	0
3.15VAC	0

. SET AT SWEEP
SET AT 0

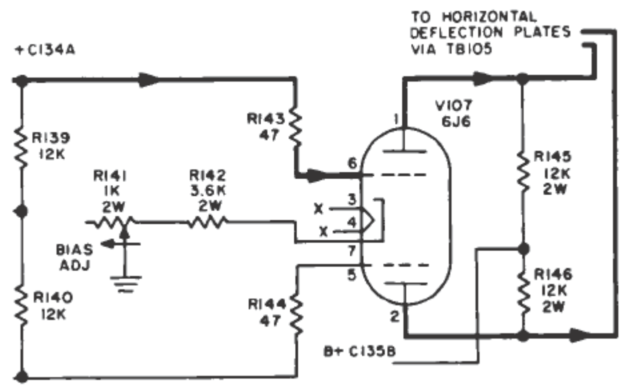
ıtal Input Circuits

778-958 O - 65 (Follows text) No. 4

CILLOSCOPE

PART OF S102
HOR. ATTEN.

WITCHED B+
O SWEEP
SCILLATOR



* V107 TABLE OF VOLTAGES AND RESISTANCES

ELEMENT	PIN NO.	VOLTAGE	RESISTANCE
PLATE (A)	1	+250V	130K
PLATE (B)	2	+250V	130K
FILAMENT	3	3.15VAC	0
FILAMENT	4	3.15VAC	0
GRID (B)	5	+72V	80K
GRID (A)	6	+72V	80K
CATHODE	7	+76V	5K

* HOR. GAIN CONTROL SET AT ZERO
HOR. ATTEN. CONTROL SET AT SWEEP

izontal Amplifiers

8-938 O - 65 (Follows text) No. 3